BEST AVAILABLE COPY

(54) Title: RAKE RECEIVER

(57) Abstract: The invention relates to a Rake receiver of a CDMA system using IRC. The Rake receiver comprises at least two antenna branches (232A, 232B), at least one Rake finger (270A, 270B), and a delay estimator (290A). The delay estimator (290A) comprises a despreader (296A, 296B) and an allocator (264) for selecting at least one delay, by which delay a multipath propagated signal component is received, and allocating a Rake finger (270A, 270B) for processing the signal component found by informing the Rake finger (270A, 270B) of the delay found. The delay estimator (290A) further comprises: a channel estimator (292), an interference estimator (292) for generating an interference signal, a weighting coefficient part (292) for providing each antenna branch (232A, 232B) with weighting coefficients maximizing the Signal-to-Interference-and-Noise Ratio (SINR), a multiplier (294A, 294B) for multiplying the pilot part by a weighting coefficient, and an antenna branch summer (298A) for combining the despread pilot parts, received via the separate antenna branches (232A, 232B) and multiplied by the weighting coefficient, to one combined pilot signal, on which combined pilot signal the selection is based in the allocator (264).

WO 01/13530 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

RAKE RECEIVER

FIELD OF THE INVENTION

The invention relates to a Rake receiver of a radio system using a Code Division Multiple Access (CDMA) method.

5   DESCRIPTION OF THE BACKGROUND ART

In radio systems, diversity methods of different kinds are used for increasing the coverage area and/or capacity of the system. As to this publication, space diversity, i.e. antenna diversity, polarization diversity and multipath diversity are of interest. Space diversity indicates that antennas are
10   positioned sufficiently far from each other to achieve a sufficient decorrelation between signals received via the separate antennas. An interesting kind of polarization diversity is implicit polarization, i.e. a signal is sent on one polarization level, but received by cross-polarized antennas. Multipath diversity refers to diversity created by multipath propagated signal components, this
15   diversity being usable in a system, such as a CDMA system, in which the bandwidth of a signal is much wider than the coherent bandwidth of a channel.

In a CDMA system, a Rake receiver is used for separating multipath propagated signal components at reception. In general, the signal components must then be separated from each other by at least one chip of a spreading
20   code used. The Rake receiver comprises Rake fingers and, in each of these fingers, despreading and diversity combination take place. In addition, the receiver comprises a delay estimator having a matched filter for each antenna branch and an allocation block for the Rake fingers. In the matched filter, a signal, received by a spreading code used for signal spreading, is correlated
25   by different delays, the timing of the spreading code then being changed for instance in steps of one chip. When the correlation is high, a multipath propagated signal component is found and it can then be received at the delay found.

On the radio path, the signal will include not only the desired signal
30   but also noise and interference caused by other users or systems. In systems utilizing diversity, the influence of noise and interference can be decreased for instance by the Maximal Ratio Combining (MRC) method, in which signals received via separate antennas are weighted in proportion to the signal power in the separate antenna branches. However, this method presupposes that the
35   interference of each antenna is independent. This presupposition is not always

2

true in actual cellular radio networks, but it is conceivable that the same interference is present at each antenna.

There is no such restriction on the Interference Rejection Combining (IRC) method. However, the method has been used only in
5   systems utilizing the Time Division Multiple Access (TDMA) method, these systems often being incapable of separating multipath propagated signal components. Herein, an IRC method refers to adaptive beam formation (optimal combination of signals), by which signal power is maximized in proportion to the power of interference and noise, i.e. the Signal-to-
10 Interference-and-Noise Ratio (SINR) is maximized. Now we shall concentrate on the code acquisition block, or delay estimator, of the receiver. It consists of L matched filters and an allocator for Rake finger allocation. The task of the matched filters is to match the spread and scrambled pilot sequence to the complex conjugated antenna signal in order to resolve the delays of the
15 channel impulse response taps. In the Rake finger allocation, the temporal Rake fingers are allocated for the different multipath components of the received signal.

The matched filters can also be implemented as a bank of parallel correlators which carry out the correlation function of the complex conjugated
20 spreading sequence. Each correlator performs despreading procedure which, mathematically, is the calculation of the cross-correlation function between the received signal and the cophasal complex conjugated spreading sequence.

The outputs of the correlators are used for allocating the Rake fingers to demodulate the strongest multipath components of the received
25 signal. The current method of Rake finger allocation is based on the energy of despread pilot symbols from L antennas. The outputs of despreaders are summed up at each code phase and N temporal Rake fingers are allocated according to the strongest energy of the sum signal. In the WCDMA (Wideband CDMA) concept the delay is estimated from the dedicated physical
30 control channel (DPCCH). The result is averaged over several time slots to get improved estimates for the Rake finger allocation process.

The current Rake finger allocation is optimal in a spatially white interference scenario, in which the interference sources are evenly distributed in the angular domain. In a spatially coloured interference field, a high-
35 powered interference source can decrease the performance of the receiver because the Rake fingers are allocated to the wrong chip delays.

BRIEF DESCRIPTION OF THE INVENTION

The present invention seeks to provide an improved Rake receiver. According to an aspect of the present invention, there is provided a Rake receiver as specified in claim 1. The preferred embodiments of the invention are claimed in the dependent claims.

The presented optimum combining scheme is capable of placing nulls towards interfering signals. Owing to this, the interference can be suppressed in Rake finger allocation. The number of the wrong Rake finger allocations can therefore be decreased, which improves the performance of the receiver. The receiver can also better track the changing interference field, and the spatial properties of interference field are taken into account in delay estimation.

LIST OF THE DRAWINGS

Embodiments of the present invention are described below, by way of example only, with reference to the attached drawings, in which

Figures 1A and 1B illustrate a mobile telephone system;

Figure 2A shows a transmitter and a receiver of a mobile telephone system;

Figure 2B illustrates spreading and modulation in a transmitter;

Figure 2C illustrates a combined descrambling, decoding and demodulation block of the receiver of Figure 2A;

Figure 2D illustrates an embodiment of the delay estimator;

Figure 2E illustrates another embodiment of the delay estimator;

Figure 3 illustrates channels of a mobile telephone system positioned in a frame;

Figure 4 illustrates the structure of user equipment in a simplified manner.

DESCRIPTION OF THE EMBODIMENTS

In the following examples, embodiments of the invention are described in the Universal Mobile Telephone System (UMTS) without restricting the invention to it.

The structure of a universal mobile telephone system is explained referring to Figures 1A and 1B. Figure 1B comprises only the blocks that are essential for the description of the invention, but it is obvious to one skilled in

4

the art that a conventional mobile telephone system also comprises other functions and structures, which need not be explained here in more detail. The main parts of a mobile telephone system are a Core Network CN, a UMTS terrestrial radio access network UTRAN and User Equipment UE. The
5   interface between the CN and the UTRAN is called Iu and the air interface between the UTRAN and the UE is called Uu.

The UTRAN comprises Radio Network Subsystems RNS. The interface between the RNSs is called Iur. An RNS comprises a Radio Network Controller RNC and one or more nodes B. The interface between the RNC
10   and B is called Iub. The coverage area of node B, i.e. a cell, is denoted by C in Figure 1B.

The description in Figure 1A is very abstract, and it is therefore clarified in Figure 1B, which shows the parts of the GSM system that approximately correspond to the parts of the UMTS. It should be noted that the
15   mapping presented is not in any way binding, but indicative, because the responsibilities and functions of the various parts of the UMTS are still under development.

In accordance with Figure 1B, a circuit-switched connection can be established from the user equipment UE to a telephone 136 connected to a
20   Public Switched Telephone Network (PSTN) 134. The user equipment UE can be for instance a fixed terminal, a terminal positioned in a vehicle or a portable terminal. The radio network infrastructure UTRAN comprises radio network subsystems RNS, i.e. base station systems. The radio network subsystem RNS comprises a radio network controller RNC, i.e. a base station controller,
25   and at least one node B, i.e. a base station, controlled by that controller.

A base station B comprises a multiplexer 114, transceivers 116 and a control unit 118 controlling the operation of the transceivers 116 and the multiplexer 114. Traffic and control channels used by a plurality of transceivers 116 are positioned on a transmission link Iub by the multiplexer 114.

30   From the transceivers 116 of the base station B, there is a connection to an antenna unit 120 implementing a bi-directional radio connection Uu to the user equipment UE. The structure of the frames to be transmitted on the bi-directional radio connection Uu is accurately defined.

The base station controller RNS comprises a switching network 110
35   and a control unit 112. The switching network 110 is used for connecting speech and data and for combining signalling circuits. The base station

system, comprising the base station B and the base station controller RNC, additionally comprises a transcoder 108. The division of tasks between the base station controller RNC and the base station B and the physical structure thereof may vary according to the implementation. The base station B typically

5   attends to the implementation of the radio path in the above-described manner. The base station controller RNC typically controls things as follows: radio resources, handover between cells, power control, timing and synchronization, paging of user equipment.

The transcoder 108 is generally situated as close to a mobile phone

10   exchange 106 as possible, because speech can then be transmitted in the form of a mobile phone system between the transcoder 108 and the base station controller RNC, thus by saving transmission capacity. The transcoder 108 converts the various digital speech coding forms between the public switched telephone network and the radio telephone network into a compatible

15   format, for instance from a 64 kbit/s format of a fixed network to another (for instance 13 kbit/s) format of the cellular radio network and vice versa. The devices required are not described here any further, but it can be stated that no other data than speech is converted by the transcoder 108. The control unit 112 performs call control and mobility management, collects statistic data and

20   performs signalling.

A core network CN consists of an infrastructure belonging to a mobile telephone system outside the UTRAN. Of the devices of the core network CN, Figure 1B illustrates the mobile phone exchange 106 and a gateway mobile phone exchange 104 which attends to the connections of the

25   mobile phone system to the outside world, here to the public switched telephone network 102.

Figure 4 shows an example of the structure of the user equipment UE. The substantial parts of the user equipment UE are: an interface 404 for an antenna 402 of the user equipment, a transceiver 406, a control part 410 of

30   the user equipment and an interface 412 for a battery 414. A user interface generally comprises a display 400, a keyboard 408, a microphone 416 and a loudspeaker 418. The user equipment may be for instance a portable mobile phone, a phone to be positioned in a car, a terminal of wireless local loop or data transmission equipment integrated into a computer.

35   The system can also employ packet-switched transmission equipment, such as the GPRS (General Packet Radio Service). The GPRS

6

(General Packet Radio Service) is a service in which air interface capacity not used in circuit-switching is employed for packet transmission. As the GPRS is a GSM-based emerging service, no details on the adaptation thereof to the UMTS will be given.

5   As Figure 1B shows, the switching field 110 can perform switching (depicted by black spots) to a public switched telephone network (PSTN) 134 through the mobile services switching centre 106 and to a packet transmission network 142. A typical terminal 136 in the public switched telephone network 134 is an ordinary or an ISDN (Integrated Services Digital Network) phone.

10   The connection between the packet transmission network 142 and the switching field 110 is established by a support node (SGSN = Serving GPRS Support Node) 140. The aim of the support node 140 is to transfer packets between the base station system and a gateway node (GGSN = Gateway GPRS Support Node) 144, and to keep record of the location of the
15   subscriber terminal UE within its area.

The gateway node 144 connects the packet transmission network 142 and a public packet transmission network 146. An Internet protocol or an X.25 protocol can be used at the interface. By encapsulation, the gateway node 144 hides the internal structure of the packet transmission network 142
20   from the public packet transmission network 146, so for the public packet transmission network 146 the packet transmission network 142 resembles a sub-network, the public packet transmission network being able to address packets to the subscriber terminal UE placed therein and to receive packets therefrom.

25   The packet transmission network 142 is typically a private network which uses an Internet protocol carrying signalling and user data. As regards the architecture and protocols below the Internet protocol layer, the structure of the network 142 may vary operator-specifically

The public packet transmission network 146 may be for example a
30   global Internet to which a terminal 148, for example a server computer, with a connection thereto wants to transfer packets to the subscriber terminal UE.

Figure 2A illustrates the function of a pair of radio transceivers. A radio transmitter may be located in a node B or in the user equipment UE and a radio receiver in the user equipment UE or in the node B.

35   The upper part of Figure 2A shows the essential functions of a radio transmitter. Various services to be located on a physical channel are for

instance speech, data, moving or stopped video image and system control channels . The figure illustrates a control channel and data processing. The various services require various source coding means; speech, for instance, requires a speech codec. However, for the sake of clarity, the source coding
5   means are not shown in Figure 2A.

Pilot bits used by the receiver for channel estimation are also located on the control channel 214. User data 200 is located on the data channel.

The various channels are then channel-coded in various ways in
10   blocks 202A and 202B. Channel coding comprises for instance different block codes, an example of them being Cyclic Redundancy Check (CRC). In addition, convolution coding and its various modifications, such as punctured convolution coding or turbo coding, are typically used. Said pilot bits are not channel-coded, however, because the intention is to find out the signal
15   distortions caused by the channel.

After the various channels have been channel-coded, they are interleaved in an interleaver 204A, 204B. The aim of interleaving is to facilitate error correction. At interleaving, the bits of the various services are scrambled together in a predetermined way, whereby an instantaneous fading on the
20   radio path alone does not necessarily make the information transmitted unfit for identification. Subsequently, the interleaved bits are spread by a spreading code in blocks 206A, 206B. The chips obtained are then scrambled by a scrambling code and modulated in block 208, the operation of which is described in more detail in Figure 2B. In this way, the separate signals are
25   combined in block 208 to be transmitted via the same transmitter.

Finally, the combined signal is brought to radio frequency parts 210, which may comprise different power amplifiers and bandwidth restricting filters. Regulation of a closed loop used for transmission power control generally controls a transmission power control amplifier located in this block. An analog
30   radio signal is then sent via the antenna 202 to the radio path Uu.

The lower part of Figure 2A illustrates the essential functions of a radio receiver. The radio receiver is typically a Rake receiver. An analog radio frequency signal is received from the radio path Uu by an antenna 232. The signal is brought to radio frequency parts 230 comprising a filter, which
35   suppresses frequencies outside the desired frequency band.

Subsequently, the signal is converted in block 228 to an

8

intermediate frequency or directly to baseband, in which form the signal is sampled and quantized. Because the signal is a multipath propagated signal, the intention is to combine the signal components propagated along different paths in block 228, the block comprising the actual Rake fingers of the

5   receiver according to the prior art technique. Block 228 is described in more detail in Figure 2C.

The physical channel obtained is then deinterleaved in a deinterleaver 226. Subsequently, the deinterleaved physical channel is divided into data streams of different channels in a demultiplexer 224. Each channel is

10   brought to a separate channel decoding block 222A, 222B, where the channel coding used for a transmission, such as block coding and convolution coding, is decoded. Convolution coding is decoded preferably by a Viterbi decoder. Each transmitted channel 220A, 220B can then be brought to be further processed, as needed, for instance data 220 is brought to a computer 122

15   connected to the user equipment UE. The control channels of the system are brought to a control part 236 of the radio receiver.

Figure 2B illustrates in more detail how a channel is spread by a spreading code and modulated. To the left in the figure, a bit stream of the channel arrives at block S/P, where each two-bit sequence is converted from

20   series form to parallel form, which means that one bit is brought to branch I of the signal and the other one to branch Q of the signal. Subsequently, the signal branches I and Q are multiplied by a spreading code c_{ch}, whereby relatively narrow-band information is spread to a wide frequency band. Each branch can have the same or a different spreading code. Each connection Uu

25   has a separate spreading code or separate spreading codes, by which the receiver identifies the transmissions intended for it. Then the signal is scrambled by multiplication with a scrambling code $c_{I \ scramb} + j \ c_{Q \ scramb}$, which is separate for each transmitter. The pulse form of the obtained signal is filtered by filters $p(t)$. Finally, the signal is modulated to a radio frequency

30   carrier by multiplying its separate branches shifted from each other by 90 degrees, the branches thus obtained are combined to one carrier ready to be sent to the radio path Uu, excluding possible filterings and power amplifications. The modulation mode described is Quadrature Phase Shift Keying QPSK.

35   Instead of the described I/Q multiplexing, time multiplexing can also be used, where data and control channels are positioned sequentially on the

time axis. However, the time difference between the channels is then so small that an interference estimated from the control channel can be assumed to be the same also on the data channel.

Maximally, 256 different mutually orthogonal spreading codes can
5 typically be used simultaneously. For instance, if the UMTS uses a five megahertz carrier at the speed of 4.096 megachips per second in the downlink direction, the spreading factor 256 corresponds to the transmission speed of 32 kbit/s, and respectively, the highest practical transmission speed is achieved by spreading factor four, whereby the data transmission speed is
10 2048 kbit/s. Accordingly, the transmission speed on the channel varies stepwise from 32, 64,128, 256, 512,1024 to 2048 kbit/s, the spreading factor being 256, 128, 64, 32, 16, 8 and 4, respectively. The data transmission speed at the user's disposal depends on the channel coding used. For instance, if 1/3 convolution coding is used, the user's data transmission speed is about one
15 third of the data transmission speed of the channel. The spreading factor informs the length of the spreading code. For instance, the spreading code corresponding to the spreading factor one is (1). The spreading factor two has two mutually orthogonal spreading codes (1,1) and (1,-1). Further, the spreading factor four has four mutually orthogonal spreading codes: below an
20 upper level spreading code (1,1), there are spreading codes (1,1,1,1) and (1,1,-1,-1), and below another upper level spreading code (1,-1), there are spreading codes (1,-1,1,-1) and (1,-1,-1,1). The formation of spreading codes is continued in this way when propagating to lower levels of a code tree. The spreading codes of a given level are always mutually orthogonal. Likewise, a
25 spreading code of a given level is orthogonal to all the spreading codes of another spreading code of the same level, which are derived from that other spreading code to next levels.

In transmission, one symbol is multiplied by a spreading code, whereby the data spreads over the frequency band to be used. For instance,
30 when the spreading code 256 is used, one symbol is represented by 256 chips. Respectively, when the spreading code 16 is used, one symbol is represented by 16 chips.

Figure 3 shows an example of which kind of frame structure can be used on a physical channel. Frames 340A, 340B, 340C, 340D are numbered
35 consecutively from one to 72 and they form a 720 milliseconds long superframe. The length of one frame 340C is 10 milliseconds. The frame 340C

is divided into sixteen slots 330A, 330B, 330C, 330D. The length of one slot 330C is 0.625 milliseconds. One slot 330C corresponds typically to one power control period, during which the power is controlled for instance by one decibel upwards or downwards.

5   The physical channels are divided into two different types: Dedicated Physical Data Channels (DPDCH) 310 and Dedicated Physical Control Channels (DPCCH) 312. The dedicated physical data channels 310 are used for transporting data 306 generated in layer two of Open Systems Interconnection (OSI) and above it, i.e. dedicated traffic channels, mainly. The dedicated physical control channels 312 transport control information generated in layer one of OSI. The control information comprises: a pilot part, i.e. pilot bits, 300 to be utilized for channel estimation, Transmit Power Control (TPC) commands 302 and, optionally, a Transport Format Indicator (TFI) 304. The transport format indicator 304 tells the receiver the transmission speed used at that moment by each dedicated physical data channel in the uplink direction.

        As appears from Figure 3, the dedicated physical data channels 310 and the dedicated physical control channels 312 are time-multiplexed into the same slot 330C in the downlink direction. In the uplink direction again, these channels are transmitted in parallel in such a way that they are IQ-multiplexed (I = Inphase, Q = Quadrature) into each frame 340C and transmitted by dual-channel Quadrature Phase Shift Keying (QPSK) modulation. When the intention is to transmit additional dedicated physical data channels 310, they are code-multiplexed either into branch I or Q of the first pair of channels.

        Subsequently, Figure 2C is examined, the figure illustrating in more detail the combined descrambling, decoding and demodulating block 228 of the receiver, shown in Figure 2A. Descrambling is not described, however, because it is of no relevance to the invention. A desired radio signal, sent to the radio path Uu, multipath propagates on an occasionally fading channel 250. Further, additive zero mean white gaussian noise 254 is combined with the signal. Moreover, interfering signals, also multipath propagating on an occasionally fading channel 252, are combined with the signal.

        Consequently, a signal to be received from the radio path Uu contains, not only the desired signal, but also both noise and interference. The signal is received by at least two separate antenna branches 232A, 232B. The

branches 232A, 232B may form an antenna array to provide antenna gain, the separate antennas being relatively close to each other, at a distance of half a wavelength, for instance. Another possibility is that the branches 232A, 232B are diversity branches, the separate antennas being relatively far from each other, at a distance of 10 to 20 wavelengths, for instance. The diversity can be implemented as space or polarization diversity.

The example of Figure 2C illustrates the use of space diversity, the branches 232A, 232B being implemented as an adaptive antenna. The adaptive antenna is implemented by antennas 232A, 232B positioned far enough from each other, via which antennas the multipath propagated signal is received.

The number of antennas may be L. The figure illustrates only two antennas, the first antenna 232A and the Lth antenna 232B. The two points between the antennas represent the existing antennas, but are not described for the sake of clarity. Generally, the number of antennas varies between two and eight.

In accordance with the invention, signals received via the separate antenna branches 232A, 232B are weighted in such a way that the influence of noise and interference can be minimized.

When diversity is used, the intention is to make the correlation between the branches as low as possible. Another way of implementing diversity is to use polarization diversity, whereby a signal is received by cross-polarized antennas. In theory, also hybrids are possible, which means that both space and polarization diversity may be used simultaneously. An example of a solution applicable to user equipment is a so-called patch antenna, which can be a plate of about a square inch in size, the plate having cross polarization planes. Another example is user equipment positioned in a vehicle, where an implementation of space diversity is also relatively easy.

A signal received from all L antenna branches 232A, 232B is brought via radio frequency parts (not shown in Figure 2C) to a delay estimator 260 connected to the antenna branch 232A, 232B. In the delay estimator 260, the delays of the best audible multipath propagated signal components are searched for. A Rake finger 270A, 270B is allocated for processing the found multipath propagated signal components. The delay estimator 260 informs each Rake branch 270A, 270B of the delay found.

The delay estimator 260 comprises a matched filter 262A, 262B for

12

each antenna branch 232A, 232B. Thus, the number of matched filters 262A, 262B is also L. In the matched filter 262A, 262B, a predetermined number of parallel correlation calculations are performed for the received radio signal by different delays in order to estimate the delays of the multipath propagated

5   signal components. In correlation calculation, the spread pilot part contained in the received radio signal is despread by a known spreading code using a predetermined delay.

On the basis of the calculated correlations, an allocator 264 situated in the delay estimator selects at least one delay, by which a multipath

10   propagated signal component is received. The allocator allocates a Rake finger 270A, 270B for processing the signal component found by informing the Rake finger of the delay found. To perform the selection, the correlation results of each matched filter 262A, 262B are typically combined in the allocator 264. If the correlation is high, a delay is found that represents the delay of the

15   multipath propagated signal component of the radio signal coming to the antenna branch 232A, 232B in question. In general, the strongest multipath components have the same code phases at all antennas, which is due to the vicinity of the antennas and to the fact that radio signals propagate at the speed of light.

20   As was said earlier, another known method for Rake finger allocation is based on the energy of despread pilot symbols from L antennas. The outputs of despreaders are summed up at each code phase and N temporal Rake fingers are allocated according to the strongest energy of the sum signal.

25   Figure 2D shows an embodiment of the delay estimator. One delay estimator 290A, 290B processes one multipath propagated signal component by a given code delay. The delay estimators 290A, 290B are described here as different instances for the sake of clarity, but they can also be realized as one instance operating internally in parallel. The delay estimator 290A, 290B

30   comprises a channel estimator 292, by which a channel impulse response of a multipath propagated signal component, included in a radio signal and found by means of a known pilot part, i.e. practically complex impulse response taps of the channel, is generated.

In addition, the delay estimator 290A, 290B comprises an

35   interference estimator 292, by which an interference signal, included in a radio signal of each antenna branch 232A, 232B and consisting of interference and

noise, is generated. The interference signal can be generated by any means known to a person skilled in the art. In an embodiment the interference estimator 292 generates an interference signal by subtracting from the received radio signal a desired regenerated radio signal. In this embodiment the desired regenerated radio signal is obtained by means of the known pilot part and the estimated impulse response of the channel. For improved performance also decision feedback of detected data bits included in the despread multipath propagated signal component can be employed in the estimation of the impulse response of the channel and the interference.

In another embodiment the interference estimator 292 generates the interference signal by using multi-user detection, whereby the signals of other users form the interference signal. More information on multiuser detection can be found in the following article: Verdu, Sergio: Adaptive Multiuser detection, published in IEEE ISSSTA '94 Proceedings of the IEEE Third International Symposium on Spread Spectrum Techniques and Applications, ISBN 07803-1750-5, which is incorporated herein by reference.

The delay estimator 290A, 290B, comprises a despreader 296A, 296B, which is connected to each antenna branch 232A, 232B and despreads the spread pilot part included in the multipath propagated signal component, by a known spreading code at a delay.

There are L despreaders for processing the pilot part, i.e. one per each antenna branch 232A, 232B in each delay estimator 290A, 290B. In practice, when despreading, the pilot part of the signal component is multiplied by a complex conjugate of the spreading code in the right phase.

A weighting coefficient part 292 in the delay estimator 290A, 290B forms weighting coefficients maximizing the signal-to-interference-and-noise ratio (SINR) for each antenna branch 232A, 232B. This can be made for instance by multiplying an inverse matrix of a covariance matrix of an interference signal, consisting of interference and noise of the antenna branches 232A, 233B, by an estimated impulse response vector of the channel. The weighting coefficients are complex.

The pilot part despread by the despreader 296A, 296B in each antenna branch 232A, 232B is multiplied by the obtained weighting coefficients by using a multiplier 294A, 294B located in the delay estimator 290A, 290B.

An antenna branch summer 298, positioned last in the delay

14

estimator 290A, 290B, combines the despread pilot parts, received via the separate antenna branches 232A, 232B and multiplied by a weighting coefficient, to one pilot signal.

5   As a whole, the situation is such that the delay estimator 290A, 290B allocates N Rake fingers 270A, 270B, for the best audible signal components. The outputs of the despreaders of different antenna branches are summed up at each code phase and N temporal Rake fingers are allocated according to the strongest energy of the sum signal.

          On the basis of the energies of the formed pilot signals, an allocator 10   264 situated in the delay estimator selects at least one delay, by which a multipath propagated signal component is received. Instead of energy values power values or calculated correlation values may also be used. Pilot signals having the highest energies are selected. The allocator 264 allocates a Rake finger 270A, 270B for processing the signal component found by informing the 15   Rake finger of the delay found. The number N may vary depending on the circumstances, or a threshold value may be set for the level of the multipath propagated signal component. Consequently, the search for timing is a dynamic process, and so is the allocation of the Rake fingers 270A, 270B to be combined.

20   In practice, a predetermined number of Rake fingers 270A, 270B, are allocated and/or a number required for delays exceeding a predetermined threshold value at correlation calculation. Generally, a limiting factor will be the maximum number of the Rake fingers 270A, 270B used. In this example, the number of allocated Rake fingers 270A, 270B is indicated by the letter N. The 25   number of signal components depends on radio conditions and, for instance, on terrain shape and buildings causing reflections. In most cases, the smallest delay by which multipath propagated signal components are searched for is one chip. The frequency of Rake finger allocation can be variable. It can be performed for each slot or each frame, for example.

30   The functioning of the delay estimator 290A can be improved by three separate filter structures. These three solutions can be used alone or combined in any way. The impulse response of the channel generated by the channel estimator 292 is averaged coherently by a first filter structure connected to the channel estimator 292. The better channel estimate thus 35   obtained also makes the weighting coefficients more reliable. The despread pilot part multiplied by the weighting coefficient is non-coherently filtered by a

15

second filter structure connected between the multiplier 294A, 294B and the antenna branch summer 298 in each antenna branch 232A, 232B. This improves the result obtained in each antenna branch 232A, 232B. The combined pilot signal is averaged non-coherently by a third filter structure

5   connected between the antenna branch summer 298 and the allocator 264.

One Rake finger 270A, 270B processes one multipath propagated signal component by a given code delay. The Rake finger 270A, 270B comprises a channel estimator 272, by which a channel impulse response of a multipath propagated signal component, included in a radio signal and found

10   by means of a known pilot part, i.e. practically complex impulse response taps of the channel, is generated.

In addition, the Rake finger 270A, 270B comprises an interference estimator 272, by which an interference signal, included in a radio signal of each antenna branch 232A, 232B and consisting of interference and noise, is

15   generated by subtracting from the received radio signal a desired regenerated radio signal. The desired regenerated radio signal is obtained by means of the known pilot part included in the radio signal and by means of the estimated impulse response of the channel.

The areas drawn with broken lines in Figure 2C illustrate the

20   processing of the pilot part 274A included in the radio signal and the processing of the data part 274B included in the radio signal.

The Rake finger 270A, 270B, comprises a despreader 276A, 276B, connected to each antenna branch 232A, 232B and despreading the spread pilot part 274A included in the multipath propagated signal component, by

25   using a known spreading code by a delay informed by the delay estimator 260.

Correspondingly, the Rake finger 270A, 270B comprises a despreader 276C, 276D, which is connected to each antenna branch 232A, 232B and despreads the spread data part 274B included in the multipath propagated signal component, by a known spreading code by a delay

30   informed by the delay estimator 260. There are L despreaders for processing both the data part and the pilot part, i.e. two per each antenna branch 232A, 232B in each Rake finger 270A, 270B. In practice, when despreading, the data part or the pilot part of the signal component is multiplied by a complex conjugate of the spreading code in the right phase.

35   As a whole, the situation is such that the delay estimator 260 allocates N Rake fingers 270A, 270B, for the best audible signal components.

16

In each Rake finger 270A, 270B, L antenna branches 232A, 232B are processed. Both the pilot part of the radio signal and the data part of the radio signal are processed separately. The number N may vary depending on the circumstances, or a threshold value may be set for the level of the multipath

5   propagated signal component. If this threshold value is exceeded, said Rake finger 270A, 270B is notified and the reception continues. Consequently, the search for timing is a dynamic process, and so is the allocation of the Rake fingers 270A, 270B to be combined.

A weighting coefficient part 272 in the Rake finger 270A, 270B

10   forms weighting coefficients which maximize the signal-to-interference-and-noise ratio (SINR) for each antenna branch 232A, 232B. This can be carried out for instance by multiplying an inverse matrix of a covariance matrix of an interference signal, consisting of interference and noise of the antenna branches 232A, 233B, by an estimated impulse response of the channel. The

15   weighting coefficients are complex.

The pilot part 274A despread by the despreader 276A, 276B in each antenna branch 232A, 232B is multiplied by the obtained weighting coefficients by a multiplier 284A, 284B located in the Rake finger 270A, 270B. Correspondingly, the data part 274B despread by the despreader 276C, 276D

20   in each antenna branch 232A, 232B is multiplied by the obtained weighting coefficients by a multiplier 284C, 284D. Accordingly, the signal components including the pilot part and the signal components including the data part are multiplied by the same weighting coefficients separately.

An antenna branch summer 278A, positioned last in the Rake finger

25   270A, 270B, combines the despread pilot parts 274A, received via the separate antenna branches 232A, 232B and multiplied by a weighting coefficient, to one pilot signal.

Correspondingly, an antenna branch summer 278B combines the despread data parts 274B, received via the separate antenna branches 232A,

30   232B and multiplied by a weighting coefficient, to one data signal.

The Rake receiver additionally comprises a Rake finger summer 280B combining the data signals of the Rake fingers 270A, 270B functioning by different delays to a sum data signal representing the received bits. The data bits are then brought according to Figure 2A from block 228 to block 226

35   to be deinterleaved.

The receiver presented is suitable for use both at a base station

and at user equipment. This means that both I/Q multiplexing and time multiplexing of data channel and control channel are possible.

Between the antenna branch summer 278A, 278B and the Rake finger summer 280A, 280B, there may be a real part 278A, 278B, removing

5   from the combined signal of each antenna branch its imaginary part, because the imaginary part is an error term generated during channel estimation.

In a preferred embodiment, the Rake receiver comprises a Rake finger summer 280A combining the pilot signals of the Rake fingers 270A, 270B, functioning by different delays, to a sum pilot signal representing the

10 received pilot bits. This sum pilot signal can be brought to an estimator 282 for the signal-to-inference ratio, estimating the signal-to-interference ratio of said channel. The power control of a closed loop can be controlled by the obtained signal-to-interference ratio of said channel. This is illustrated in block 282 of Figure 2C by the text TPC (Transmission Power Control).

15   The invention is implemented preferably by software, at least part of the functions included in block 228 being changed to software to be performed by a processor. However, the delay estimator 260, 290A requiring a high calculation capacity is preferably implemented as an Application Specific Integrated Circuit (ASIC). The other functions included in block 228 can also

20 be implemented by device solutions offering the needed functionality, such as an ASIC or a discrete logic.

A method of calculating weighting coefficients maximizing the SINR is presented next, assuming that the impulse response h of the channel and the covariance matrix R_{uu} of interference and noise are known. The method

25 can be used both in the Rake fingers 270A, 270B and in the delay estimator 290A. Subsequently, a method of estimating h and R_{uu} by means of known pilot bits included in a signal is presented. The presentation is a complex baseband signal model on symbol level for processing the signal. In the presentation, the bold face terms illustrate a vertical vector or a matrix. Let us

30 assume that N multipath propagated Signals Of Interest (SOI) are found on time axis by matched filters, and each signal component is received via L separate antennas. The L complex channel taps of the Nth multipath propagated signal component are indicated by vectors h_n having a length L. The additive Multi Access Interference (MAI) caused by other users, multipath

35 self-interference and noise are indicated by a vector u_n, which is modelled as an L-variate complex Gaussian distributed process with spatial possibly

coloured covariance $R_{uu,n} = E[u_n u_n^H]$. The signal received from the L antennas is indicated by a vector r_n. An information symbol of the Mth user out of an alphabet of size M is indicated by the term s_m.

5   The Gaussian assumption for the despread MAI is valid for a great number of spreading factors having different lengths.

Subsequently, each symbol period is discretized into K samples, whereby the vector r_n can be presented in the form:

$$r_n[k] = h_n\, s_m[k] + u_n[k], \quad k = 1,\ldots,K \tag{1}$$

10

By stacking each of the N vectors to vectors having a length LN, a more compact notation is obtained:

$$r[k] = h\, s_m[k] + u[k], \quad k = 1,\ldots,K \tag{2}$$

15

The Gaussian distributed interference variables $u_n[k]$ and $u[k]$ are mutually uncorrelated across sampling instants and also across the different multipath propagated components of SOI. Then:

20        $$R_{uu}[k] = E\big[u[k]u^H[k]\big] = diag\big(R_{uu,1}[k],\ldots,R_{uu,N}[k]\big) \tag{3}$$

Assuming that the symbols s_m are equi-probable and the channel parameters h and the covariance matrix $R_{uu}[k]$ of interference and noise are both known, the optimal demodulation involves the maximization of the log 25   likelihood function ($|\cdot|$ denotes determinant):

$$L(\mathbf{r},s_m) = \ln\Big(\prod_{k=1}^{K}\frac{1}{\pi^{LN}|R_{uu}[k]|}\exp\big(-u[k]R_{uu}^{-1}[k]u^H[k]\big)\Big)$$

$$= -\sum_{k=1}^{K}(r[k] - h\,s_m[k])^H R_{uu}^{-1}[k](r[k] - h\,s_m[k]) + const, \tag{4}$$

Assuming that the symbols have the same energy, formula 4 can 30   be developed into the form:

$$L(\mathbf{r}, \mathbf{s}_m) = \sum_{k=1}^{K} 2\operatorname{Re}\left\{\mathbf{r}^H[k]\mathbf{R}_{uu}^{-1}[k]\mathbf{h}\, s_m[k]\right\} + const_2$$

$$= 2\operatorname{Re}\left\{\sum_{k=1}^{K}\left(\sum_{n=1}^{N}\mathbf{w}_n^H[k]\mathbf{r}_n[k]\right)s_m^*[k]\right\} + const_2 \qquad (5)$$

$$= 2\operatorname{Re}\left\{\mathbf{s}_m^H\, \mathbf{t}\right\}$$

whereby the N weighting coefficients minimizing the interference are $\mathbf{w}_n[k] = \mathbf{R}_{uu,n}^{-1}[k]\mathbf{h}_n$, and the vectors $\mathbf{s}_m$ and $\mathbf{t}$ have a length K with elements

5   $s_m[k]$, respectively

$$\sum_{n=1}^{N}\mathbf{w}_n^H[k]\mathbf{r}_n[k].$$

Accordingly, the IRC Rake receiver presented earlier can be decomposed into N temporal Rake fingers, each of which performs spatial IRC on the L antenna inputs by using weighting coefficients $\mathbf{w}_n[k] = \mathbf{R}_{uu,n}^{-1}[k]\mathbf{h}_n$. The

10   outputs of the Rake fingers are summed, i.e. combined, and a correlation detector is applied to determine for the symbol s_m a value enabling the largest symbol correlation metric.

If the multipath self-interference of SOI can be neglected, for instance when the processing gain is large enough, the $\mathbf{R}_{uu,n}$ is essentially the

15   same in all N fingers, which means that it needs to be estimated and inverted only once. When the interference covariance matrix is spatially white, i.e. $\mathbf{R}_{uu,n}$ = Id, IRC becomes MRC, because $\mathbf{w}_n[k] = \mathbf{h}_n$. Direct Matrix Inversion (DMI) of the matrix $\mathbf{R}_{uu,n}$ can be avoided, if recursive algorithms, such as Least Mean Square (LMS) or Recursive Least Square (RLS), are used. Accordingly, the

20   receiver can be constructed in such a way that the interference elimination method can be changed according to the circumstances between the MRC and IRC. When data transmission speeds are high, the interference is coloured, and therefore, IRC is used, and, respectively, MRC is used at low data transmission speeds. In principle, MRC is only one special case of IRC,

25   which means that the method to be used can always be IRC.

Assuming that $\mathbf{h}$ and $\mathbf{R}_{uu}$ are not known, an unstructured Maximum Likelihood ML channel estimation of vector $\mathbf{h}$ and an estimation of the covariance matrix $\mathbf{R}_{uu}$ utilizing the performed channel estimation are presented next. As stated earlier, I/Q multiplexing is used in the uplink direction, the data

30   channel being multiplexed to the branch I and the control channel to the branch Q. The control channel also comprises a previously known pilot part. Both channels can be separated from each other by despreading with

20

orthogonal spreading codes. The symbol-level signal model is obtained from equation 1, by writing it separately for each part, I and Q, using BPSK symbols $s_m \in \{-1,1\}$. It is further assumed that the index k now refers to the bit index of the symbol sequence. K bits of DPCCH are collected into one slot.

5   Previously, the channel parameters h and the interference covariance R_{uu} were assumed to be known. Now, it is assumed that no a priori information on either spatial structure is available, which means that the optimal channel estimates are created on the maximum likelihood principle. The vector r[k], k=1,...,K and the pilot bits $s_p[k]$ of the DPCCH within one slot
10   are used, by which ML estimates $[\hat{h}, \hat{R}_{uu}]$ are generated, being the joint minimizers of the log likelihood function:

$$
\begin{aligned}
L(r,h,R_{uu}) &= \\
&= \ln(\prod_{k=1}^{K} \frac{1}{\pi^{LN}|R_{uu}[k]|} \exp\{-(r[k]-hs_p[k])^H R_{uu}^{-1}[k](r[k]-hs_p[k])\}) \\
&= -\ln|R_{uu}^{-1}| - trace\{R_{uu} \frac{1}{K}\sum_{k=1}^{K}(r[k]-hs_p[k])\} + const_1
\end{aligned}
\tag{6}
$$

15   This ML estimating problem is separable. When ML is given the estimate $\hat{h}$, the vector will be $\hat{R}_{uu}$:

$$
\hat{R}_{uu} = \frac{1}{K}\sum_{k=1}^{K}(r[k]-\hat{h}s_p[k])(r[k]-\hat{h}s_p[k])^H
\tag{7}
$$

20   and the ML estimate $\hat{h}$ is obtained as the minimizer of the cost function ($|\cdot|$ denotes determinant):

$$
\begin{aligned}
F &= \left| \frac{1}{K}\sum_{k=1}^{K}(r[k]-hs_p[k])(r[k]-hs_p[k])^H \right| \\
&= \left| (h-\hat{r}_{sr}^H)(h-\hat{r}_{sr}^H)^H + \hat{R}_{rr} - \hat{r}_{sr}^H \hat{r}_{sr} \right|
\end{aligned}
\tag{8}
$$

25   where $\hat{r}_{sr} = \frac{1}{K}\sum_{k=1}^{K} s_p[k]r^H[k], \quad \hat{R}_{rr} = \frac{1}{K}\sum_{k=1}^{K} r[k]r^H[k]$

F is minimized for the choice:

$$
h = \hat{r}_{sr}^H
\tag{9}
$$

Instead of estimating R_{uu} from the despread signal, the wideband signal can be used for the covariance matrix estimation. In that approach we calculate R_{rr} instead of R_{uu} and use that term to suppress the interference. In

5　the R_{rr} estimation we have lots of samples and due to that the accuracy of the estimation can be increased. Also, in that approach, the covariance matrix needs to be calculated and inverted only once for all chip delay positions. So the computational load can be decreased. The R_{uu} is the spatial correlation matrix of the interference plus noise and the R_{rr} is the spatial correlation matrix

10　of the signal plus interference plus noise. The R_{uu} approach is described in Figure 2D, and the R_{rr} approach in Figure 2E. Figure 2E is otherwise the same as Figure 2D but the interference estimator 286 estimates the R_{rr} from the received wideband signal, and passes this information to the weighting coefficient part 288.

15　A linear channel estimator based on pilot bits has been described above. It is obvious to one skilled in the art that known more developed channel estimation methods, such as methods utilizing a data channel as well, can be applied to the method of the invention.

In the radio system described, there may occur interference caused

20　by the frequency band adjacent to the desired channel in some situations, this interference being known as Adjacent Channel Power (ACP). The adjacent frequency band may be the WCDMA frequency band adjacent to said operator, the WCDMA frequency band of another operator or a frequency band of some other system, for instance the GSM system. The problem may

25　cause blocking in the cell in the uplink direction. For instance, let us assume that a high efficiency GSM transmitter causes ACP to a Rake receiver operating at a high data speed, i.e. at a low spreading ratio, on a 5-MHz frequency band, for instance. The ACP (as interference in general) must be above the noise level so that it can be eliminated. In accordance with the

30　invention, an interference signal generated by the interference estimator 272 then comprises interference caused by the adjacent frequency band of the desired channel, i.e. adjacent channel power, the detrimental effect of which can thus be eliminated. A shrinking of the cell on account of ACP can thus be prevented.

35　Though the invention has been described above with reference to the example of the attached drawings, it is clear that the invention is not

22

restricted to that, but can be modified in many ways within the scope of the inventive idea of the attached claims.

23

CLAIMS

1. A Rake receiver comprising at least two antenna branches (232A, 232B) for receiving a radio signal, at least one Rake finger (270A, 270B) connected to the antenna branches (232A, 232B) for processing a
5   multipath propagated signal component of the radio signal, and a delay estimator (290A) connected to the antenna branches (232A, 232B), the delay estimator (290A) comprising:

a despreader (296A, 296B) connected to each antenna branch (232A, 232B) for despreading the pilot part included in the multipath
10   propagated signal component by using a known spreading code by a delay;

and an allocator (264) for selecting at least one delay, by which delay a multipath propagated signal component is received, and allocating a Rake finger (270A, 270B) for processing the found signal component;

c h a r a c t e r i z e d in that the delay estimator (290A) further
15   comprises:

a channel estimator (292) for generating an impulse response of the channel of the multipath propagated signal component found by means of a known pilot part included in the radio signal of each antenna branch (232A, 232B);

20   an interference estimator (292) for generating an interference signal, included in the radio signal of each antenna branch (232A, 232B) and consisting of interference and noise;

a weighting coefficient part (292) for providing each antenna branch (232A, 232B) with weighting coefficients maximizing the Signal-to Interference-
25   and-Noise Ratio (SINR);

a multiplier (294A, 294B) for multiplying the pilot part, despread by the despreader (296A, 296B) in each antenna branch (232A, 232B), by a weighting coefficient;

an antenna branch summer (298A) for combining the despread pilot
30   parts, received via the separate antenna branches (232A, 232B) and multiplied by the weighting coefficient, to one combined pilot signal, on which combined pilot signal the selection is based in the allocator (264).

2. A Rake receiver according to claim 1, c h a r a c t e r i z e d in that the interference estimator (292) generates one interference signal that is
35   used for all different delays.

24

3. A Rake receiver according to claim 1, c h a r a c t e r i z e d in that the interference estimator (292) generates interference signal for each delay.

4. A Rake receiver according to claim 3, c h a r a c t e r i z e d in that for each delay its own interference signal is used.

5. A Rake receiver according to claim 3, c h a r a c t e r i z e d in that an average interference signal is calculated using the interference signals of each delay, and this average interference signal is used for each delay.

6. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that the interference estimator (292) uses as an input the despread pilot part (274A) included in the multipath propagated signal component by using a known spreading code by a delay.

7. A Rake receiver according to any preceding claim 1 to 5, c h a r a c t e r i z e d in that the interference estimator (292) uses as an input the received radio signal.

8. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that the interference estimator (292) generates an interference signal by subtracting from the received radio signal a desired regenerated radio signal.

9. A Rake receiver according to claim 8, c h a r a c t e r i z e d in that the desired regenerated radio signal is obtained by means of the known pilot part and the estimated impulse response of the channel.

10. A Rake receiver according to claim 8 or 9, c h a r a c t e r i z e d in that the desired regenerated radio signal is obtained by means of decision feedback of detected data bits included in the despread multipath propagated signal component.

11. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that the interference estimator (292) generates an interference signal by using multi-user detection, whereby the signals of other users form the interference signal.

12. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that the impulse response of the channel generated by the channel estimator (292) is averaged coherently by a first filter structure connected to the channel estimator (292).

13. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that the despread pilot part multiplied by the

weighting coefficient is non-coherently filtered by a second filter structure connected between the multiplier (294A, 294B) and the antenna branch summer (298) in each antenna branch (232A, 232B).

14. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that the combined pilot signal is averaged non-coherently by a third filter structure connected between the antenna branch summer (298) and the allocator (264).

15. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that the despreader (296A, 296B) is replaced by a matched filter (262A, 262B) for each antenna branch (232A, 232B) for performing a predetermined number of parallel correlation calculations for the received radio signal by different delays, whereby the pilot part included in the received radio signal is despread in correlation calculation by a known spreading code at a predetermined delay.

16. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that, to provide antenna gain, the antenna branches (232A, 232B) form an antenna array, by which an antenna beam is formed in the desired direction by phasing separate antenna signals.

17. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that the antenna branches (232A, 232B) are diversity branches.

18. A Rake receiver according to claim 17, c h a r a c t e r i z e d in that the antenna branches (232A, 232B) are antennas implemented by space diversity.

19. A Rake receiver according to claim 17, c h a r a c t e r i z e d in that the antenna branches (232A, 232B) are antennas implemented by polarization diversity.

20. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that the channel estimator (272) performs the channel estimation on the optimal Maximum Likelihood principle.

21. A Rake receiver according to any preceding claim, c h a r a c t e r i z e d in that weighting coefficients maximizing the signal-to-interference-and-noise ratio are formed for each antenna branch (232A, 232B) by multiplying an inverse matrix of a covariance matrix, generated of an interference signal of the antenna branches (232A, 232B), by an estimated impulse response of the channel.

26

22. A Rake receiver according to claim 21, **c h a r a c t e r i z e d** in that a channel estimate generated by the optimal Maximum Likelihood method is utilized for estimating the covariance matrix generated of interference and noise.

5   23. A Rake receiver according to any preceding claim, **c h a r a c t e r i z e d** in that the interference signal generated by the interference estimator (272) comprises interference caused by the adjacent frequency band of the desired channel, i.e. adjacent channel power.
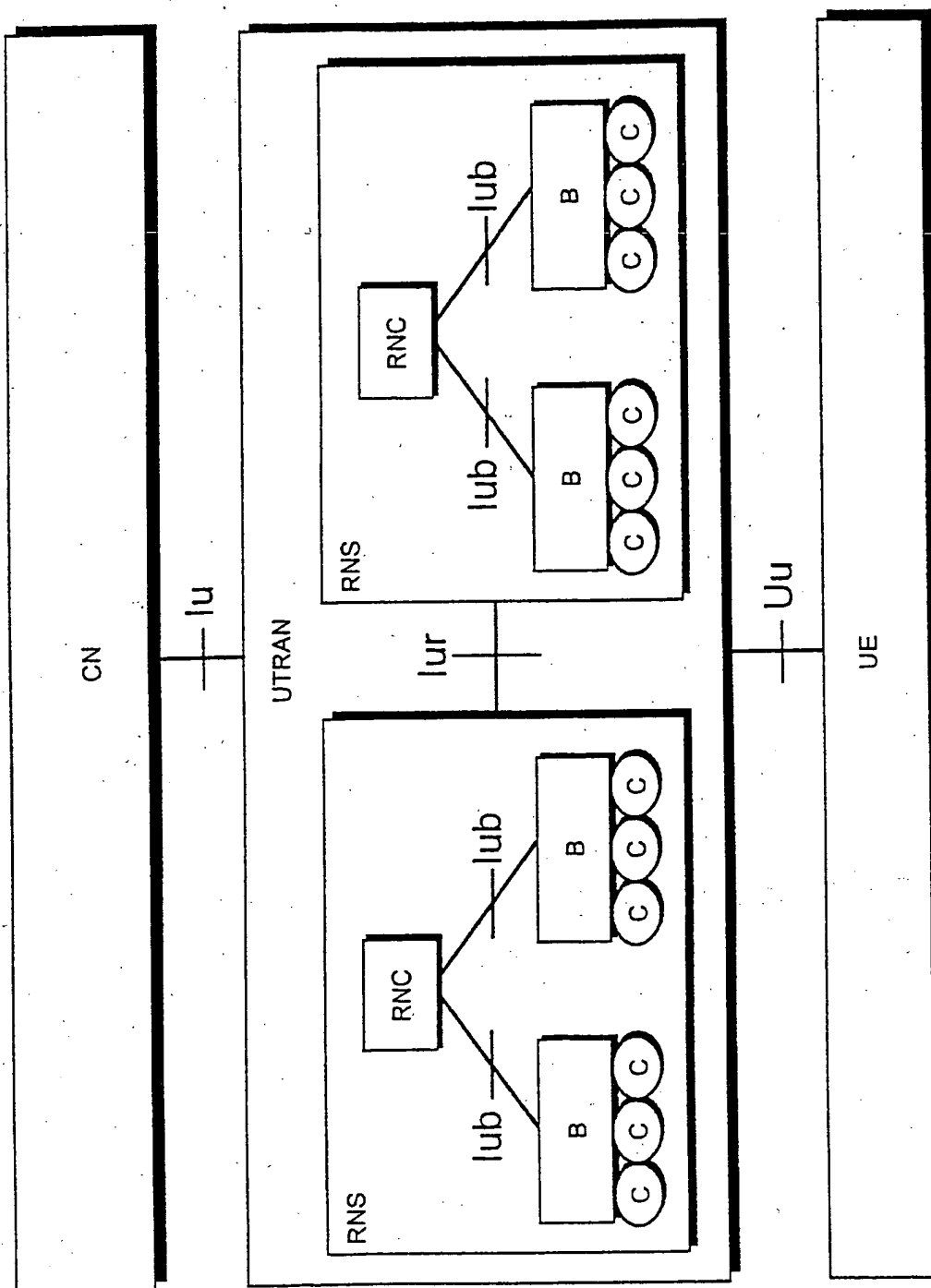
Fig 1A
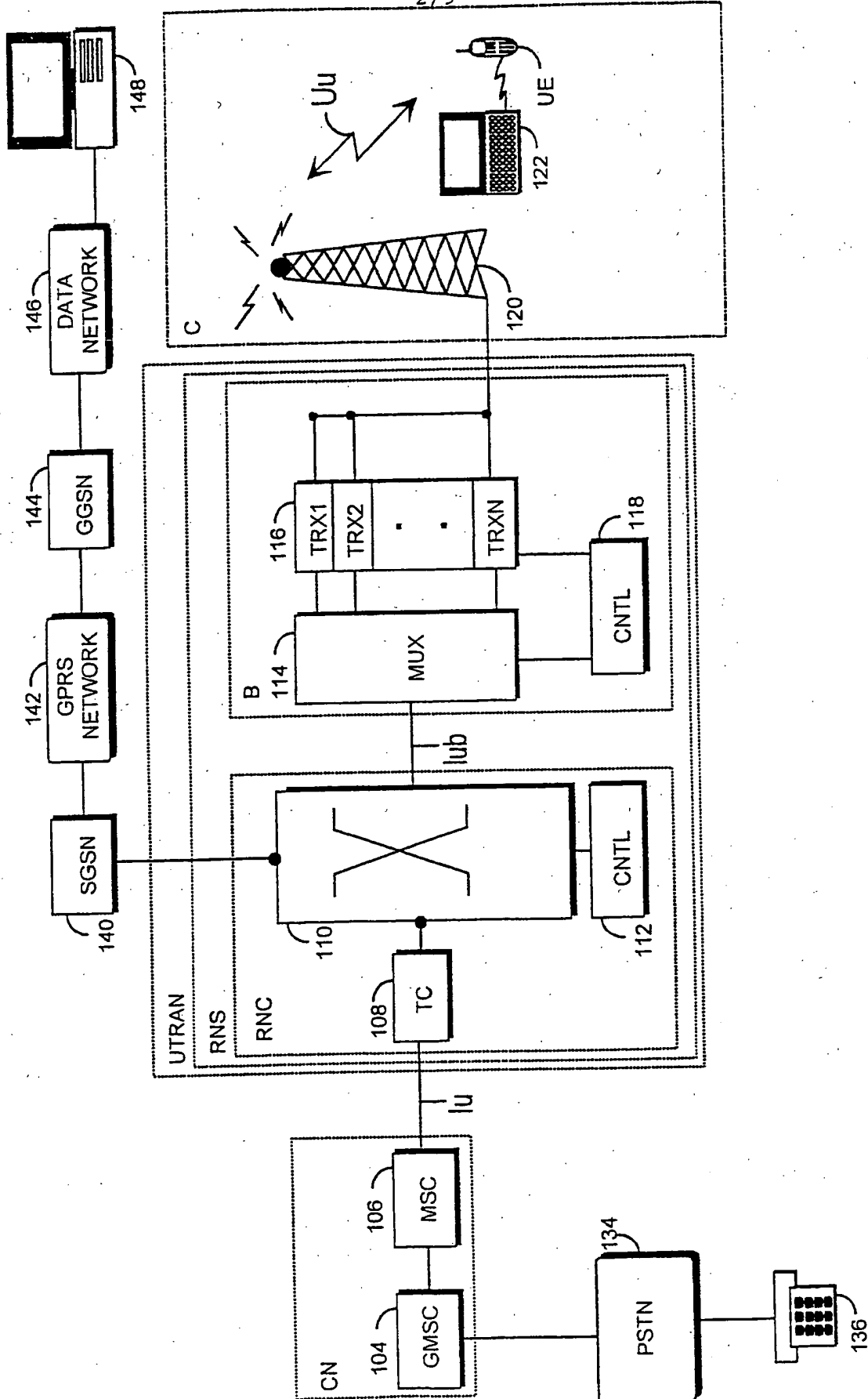
Fig 1B
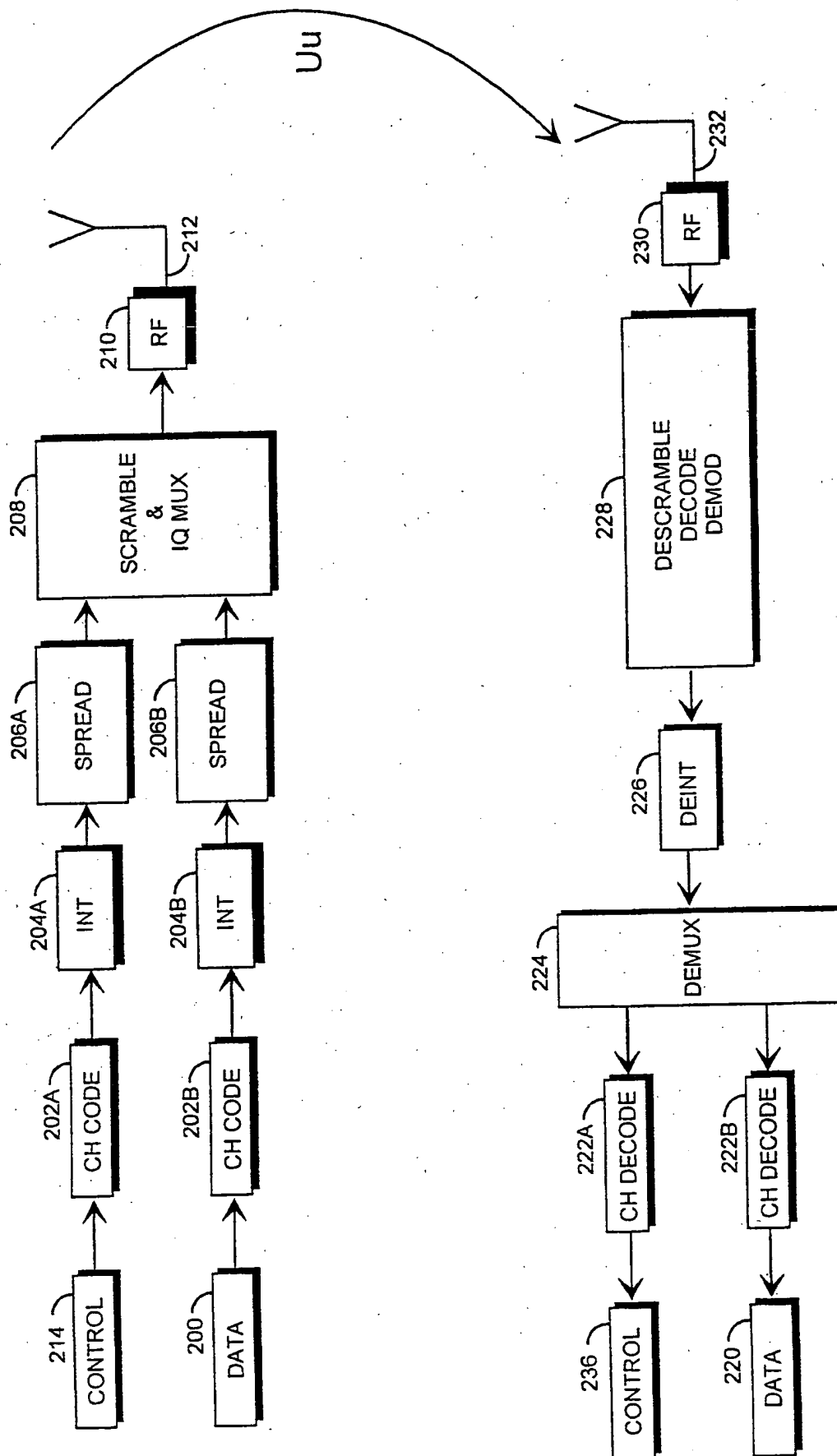
Fig 2A
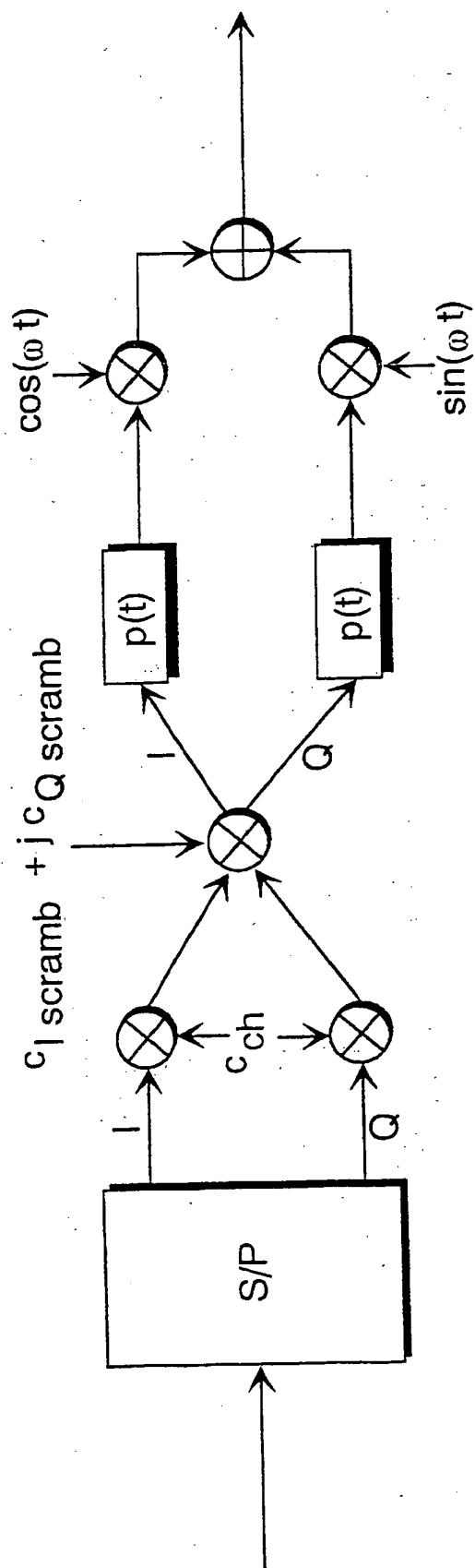
Fig 2B

Fig 2C

Fig 2D

Fig 2E

Fig 3

UE

416

418

414
BATT

412

410
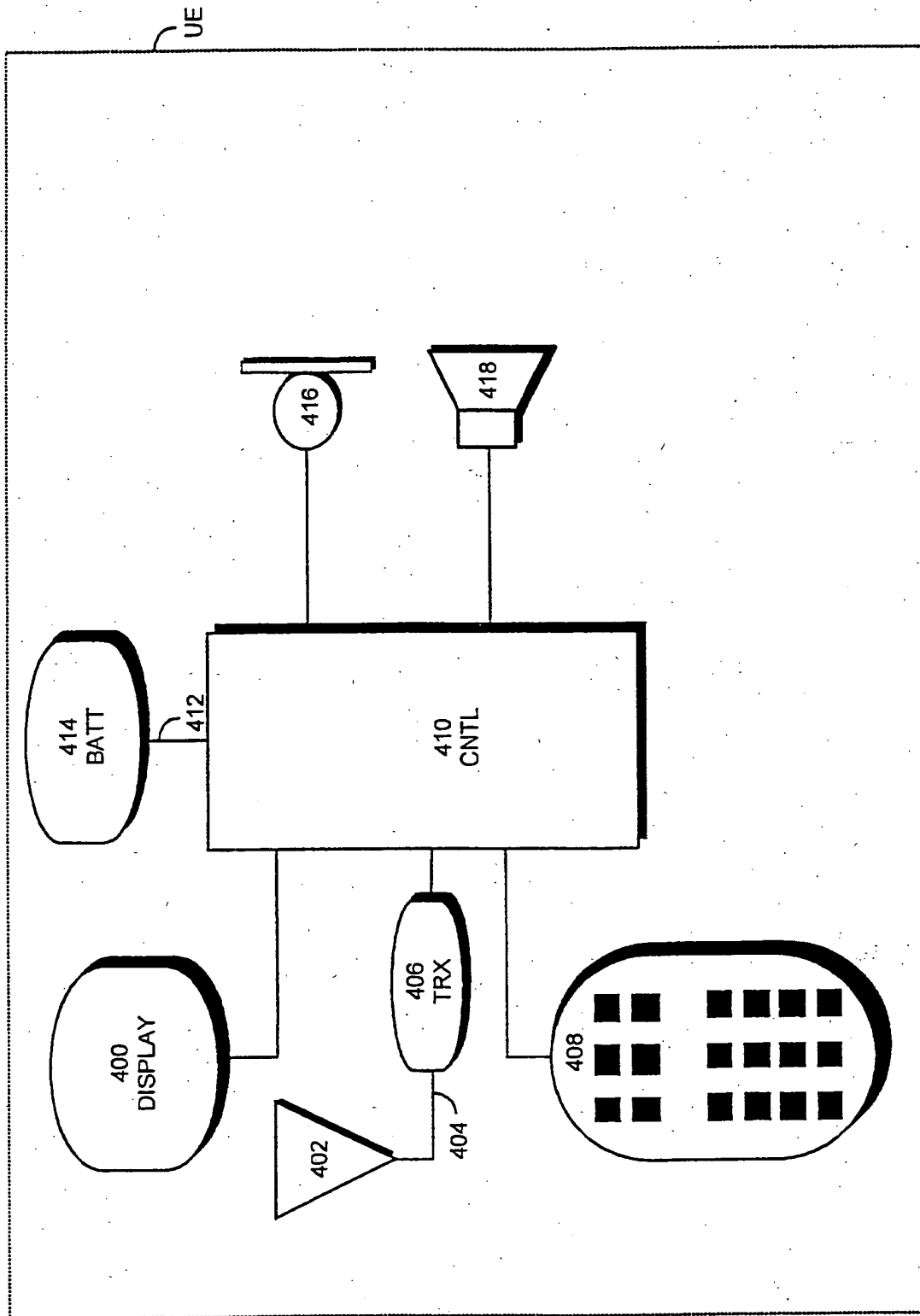CNTL

400
DISPLAY

402

406
TRX

404

408
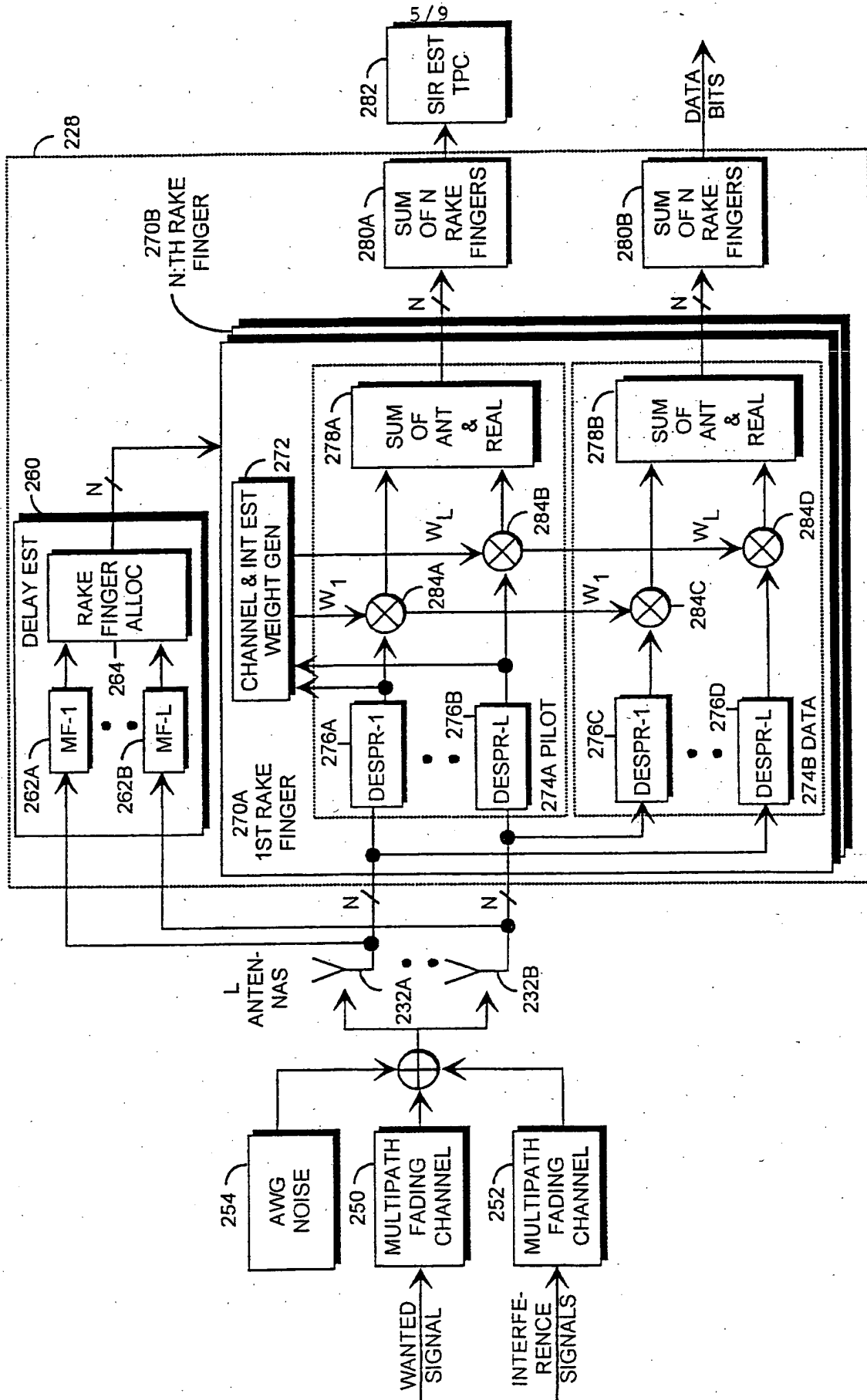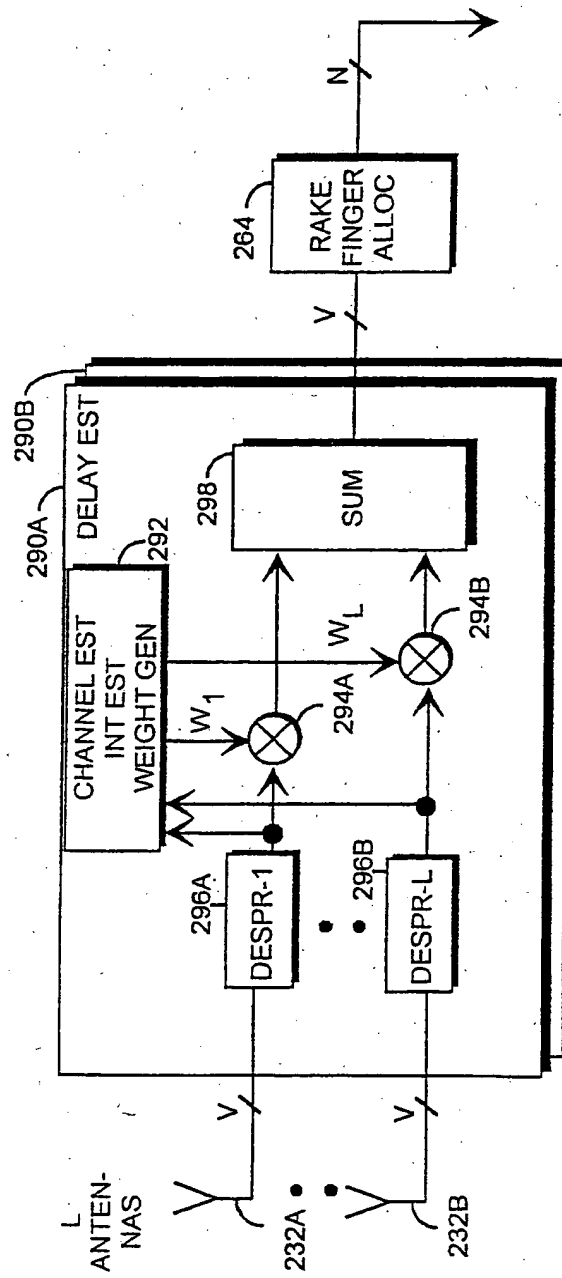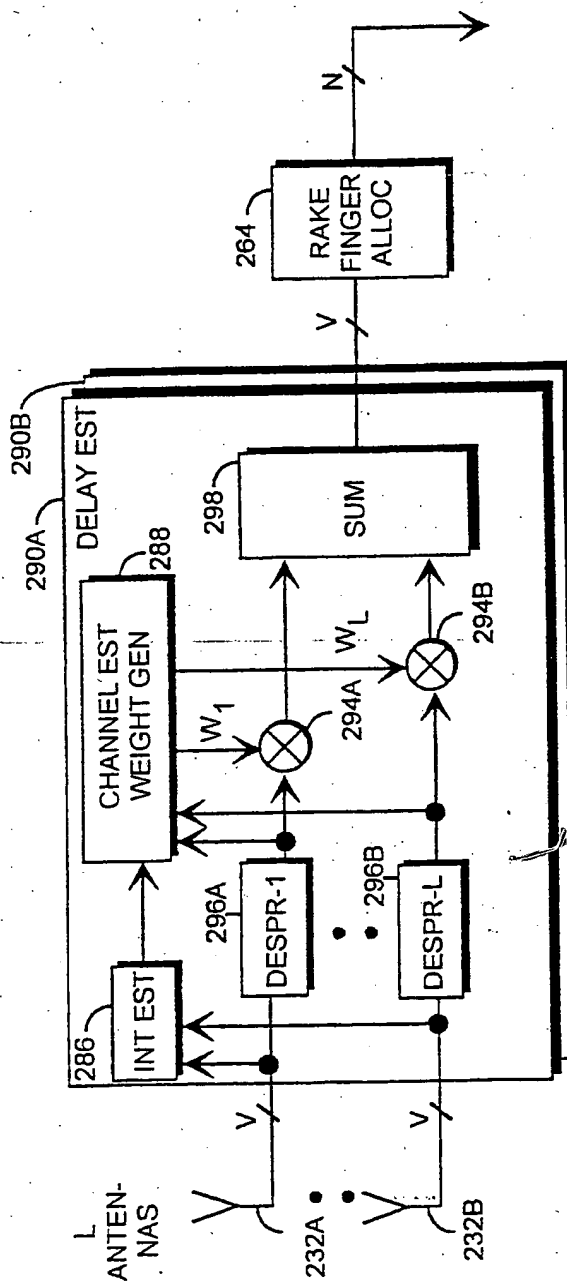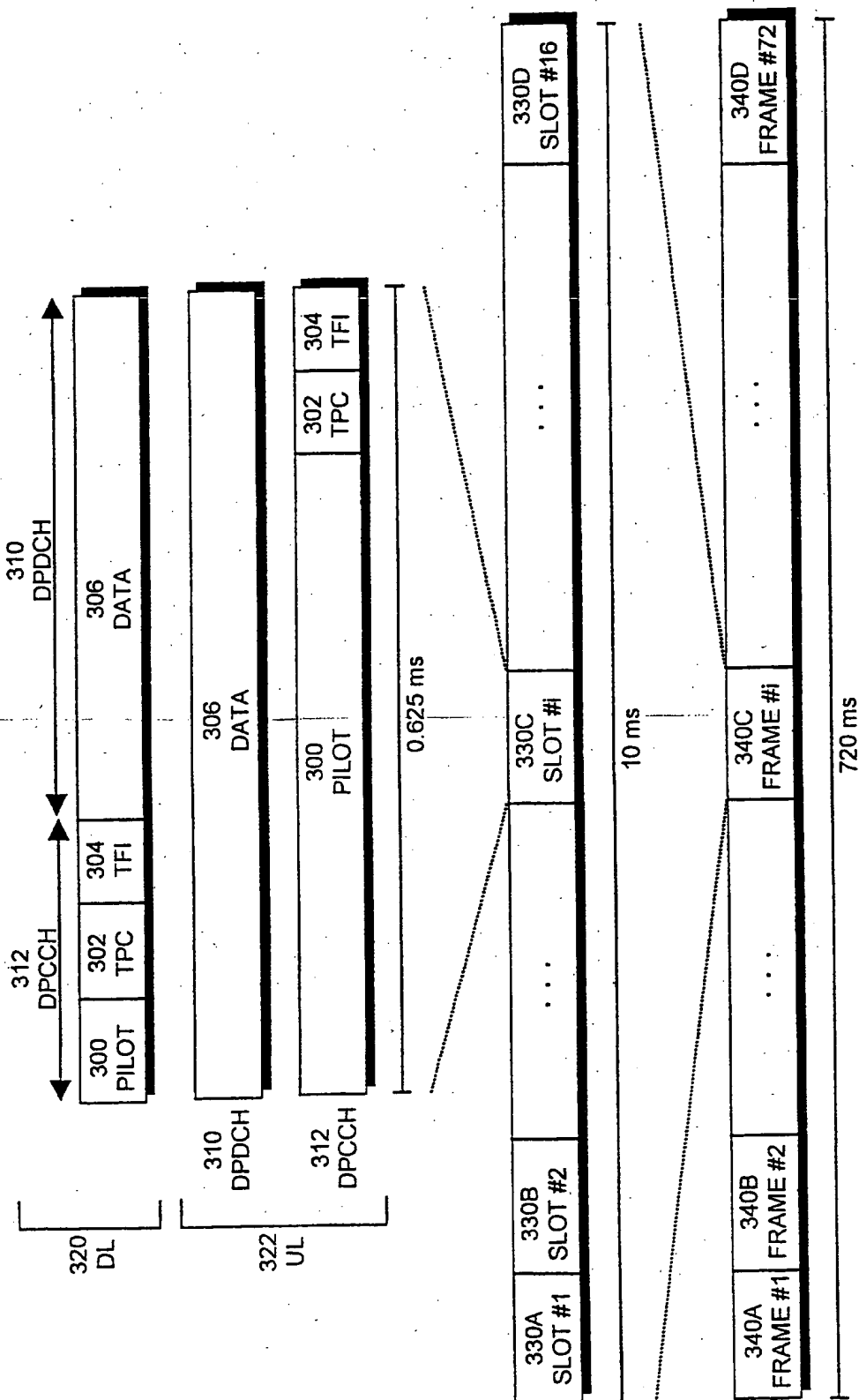
Fig 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 99/00984

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04B 1/707
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E,X	WO 00/16494 A1 (NOKIA NETWORKS OY), 23 March 2000 (23.03.00), page 11, line 10 - line 24, claim 1, abstract	1-23
A	WO 99/35763 A1 (ERICSSON INC.), 15 July 1999 (15.07.99), abstract	1-23
A	US 5680419 A (GREGORY E. BOTTOMLEY), 21 October 1997 (21.10.97), abstract	1-23
A	WO 94/28640 A1 (ROKE MANOR RESEARCH LIMITED), 8 December 1994 (08.12.94), claim 1, abstract	1-23

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	erlier document but published on or after the international filing date	"X"	document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 Sept 2000	11 -09- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer FREDRIK BLOMQVIST/EE Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

02/12/99

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 00/16494 A1	23/03/00	NONE	
WO 99/35763 A1	15/07/99	NONE	
US 5680419 A	21/10/97	AU 691953 B	28/05/98
		AU 3150795 A	04/03/96
		BR 9508455 A	09/06/98
		CA 2195849 A	03/02/96
		CN 1157073 A	13/08/97
		EP 0775405 A	28/05/97
		FI 970414 A	27/03/97
		JP 11509377 T	17/08/99
		NO 970389 A	02/04/97
		WO 9604738 A	15/02/96
WO 94/28640 A1	08/12/94	NONE	